

What is claimed is:

1. An optical system of an optical pick-up for recording data to and/or reproducing data from at least two types of optical discs including a first optical disc and a second optical disc whose recording density is higher than that of the first optical disc, comprising:

a light source unit that is capable of emitting at least two light beams having different wavelengths respectively corresponding to the first and second optical discs;

an objective lens that is used for respectively converging the at least two light beams on data recording surfaces of the at least two types of optical discs; and

a photo detector that has a main sensor for receiving a main beam of returning light from a disc side, and sub-sensors for receiving sub-beams of the returning light from the disc side,

wherein said optical system further comprises an optical surface to satisfy compatibility between the at least two types of optical discs, said optical surface being located between said light source unit and one of the at least two type of optical discs;

wherein said optical surface comprises:

an inner region including an optical axis of said objective lens and satisfying a numerical aperture for the

first optical disc;

an outer region located outside said inner region for satisfying a numerical aperture for the second optical disc; and

an intermediate region that is located within said outer region at a periphery of the inner region,

wherein transmissivity for a light beam having a wavelength suitable for the first optical disc in said intermediate region is lower than that in said inner region.

2. The optical system according to claim 1,

wherein when the first optical disc is tilted by a certain minute angle with respect to a plane perpendicular to the optical axis of said objective lens during reproducing operation of the first optical disc, intensity of a portion of the returning light passed through said intermediate region is reduced on the sub-sensors of said photo detector so that the portion of the returning light does not interfere with photo detection operation of the sub-sensors.

3. The optical system according to claim 1,

wherein transmissivity for a light beam having a wavelength suitable for one of the at least two types of optical discs other than the first optical disc in said intermediate region is substantially the same as that of said inner region

and said outer region,

wherein when the one of the at least two types of optical discs other than the first optical disc is used, the light beam for the one of the at least two types of optical discs other than the first optical disc passed through all of said inner region, said intermediate region and said outer region is utilized.

4. The optical system according to claim 1,

wherein the transmissivity for the light beam having the wavelength suitable for the first optical disc in said intermediate region is about half of or less than half of transmissivity for the light beam having the wavelength suitable for the first optical disc in said inner region.

5. An optical system of an optical pick-up for recording data to and/or reproducing data from at least two types of optical discs including a first optical disc and a second optical disc whose recording density is higher than that of the first optical disc, comprising:

a light source unit that is capable of emitting at least two light beams having different wavelengths respectively corresponding to the first and second optical discs;

an objective lens that is used for respectively converging the at least two light beams on data recording surfaces of the

at least two types of optical discs; and

a photo detector that has a main sensor for receiving a main beam of returning light from a disc side, and sub-sensors for receiving sub-beams of the returning light from the disc side;

wherein said optical system further comprises an optical surface to satisfy compatibility between the at least two types of optical discs, said optical surface being located between said light source unit and one of the at least two types of optical discs;

wherein said optical surface comprises:

an inner region including an optical axis of said objective lens and satisfying a numerical aperture for the first optical disc;

an outer region located outside said inner region for satisfying a numerical aperture for the second optical disc; and

an intermediate region that is located within said outer region at a periphery of the inner region,

wherein said intermediate region has a plurality of minute annular zones for giving optical path differences to an incident beam, an absolute value of each optical path difference generated between adjacent ones of the plurality of minute annular zones is  $N+0.5$  times ( $N$ : natural number) as large as the wavelength of the light beam suitable for the first

optical disc.

6. The optical system according to claim 5,

wherein when the first optical disc is tilted by a certain minute angle with respect to a plane perpendicular to the optical axis of said objective lens during reproducing operation of the first optical disc, intensity of a portion of the returning light passed through said intermediate region is reduced on the sub-sensors of said photo detector so that the portion of the returning light does not interfere with photo detection operation of the sub-sensors.

7. The optical system according to claim 5, wherein N is smaller than or equal to 5.

8. The optical system according to claim 8,

wherein the each optical path difference generated between adjacent ones of the plurality of minute annular zones is an integral multiple of a wavelength of a light beam for one of the at least two types of optical discs other than the first optical disc, the integral multiple being exclusive of zero,

wherein when the one of the at least two types of optical discs other than the first optical disc is used, the light beam for the one of the at least two types of optical discs other than the first optical disc passed through all of said inner

region, said intermediate region and said outer region is utilized.

9. The optical system according to claim 5,

wherein the plurality of minute annular zones has repetition of a pair of zones that give optical path differences whose signs are different from each other.

10. The optical system according to claim 9,

wherein a size of each of protruded surfaces of the plurality of minute annular zones is larger than a size of each of recessed surfaces of the plurality of minute annular zones.

11. The optical system according to claim 5,

wherein a width  $W_z$  of each of the plurality of minute annular zones satisfies a condition  $0.005 \text{ mm} \leq W_z \leq 0.020 \text{ mm}$  when the plurality of minute annular zones are projected to a plane perpendicular to a reference axis of said optical system.

12. The optical system according to claim 5,

wherein said optical system satisfies a condition:

$$0.0035 < \{W \cdot (\phi_2/\phi_1)\} / \{(1-M) \cdot f\} < 0.0350 \quad \cdots \cdots (1)$$

where  $W$  (mm) represents a width of said intermediate region when the intermediate region is projected onto a plane perpendicular to a reference axis of said optical system,  $f$  (mm)

represents a focal length of said objective lens for the wavelength of the light beam for the first optical disc,  $M$  represents a magnification of said objective lens when the first optical disc is used,  $\phi_1$  (mm) represents a diameter of said inner region, and  $\phi_2$  (mm) represents a diameter of the light beam incident on said inner region when the diameter  $\phi_2$  is measured on a light source side surface of said objective lens.

13. The optical system according to claim 5, wherein said optical surface to satisfy the compatibility is formed on one of surfaces of said objective lens.

14. The optical system according to claim 5, wherein said intermediate region adjoins said inner region.

15. An objective lens used for an optical system of an optical pick-up for recording data to and/or reproducing data from at least two types of optical discs including a first optical disc and a second optical disc whose recording density is higher than that of the first optical disc, one of surfaces of said objective lens comprising:

an inner region including an optical axis of said objective lens and satisfying a numerical aperture for the first optical disc;

an outer region located outside said inner region for

satisfying a numerical aperture for the second optical disc;  
and

an intermediate region that is located within said outer region at a periphery of the inner region,

wherein transmissivity for a light beam having a wavelength suitable for the first optical disc in said intermediate region is lower than that in said inner region.

16. The objective lens according to claim 15,

wherein when the first optical disc is tilted by a certain minute angle with respect to a plane perpendicular to the optical axis of said objective lens during reproducing operation of the first optical disc, a portion of returning light from a disc side is incident on said intermediate region, almost all of the portion of returning light incident on said intermediate region being shielded by said intermediate region.

17. The objective lens according to claim 15,

wherein transmissivity for a light beam having a wavelength suitable for one of the at least two types of optical discs other than the first optical disc in said intermediate region is substantially the same as that of said inner region and said outer region,

wherein when the one of the at least two types of optical



discs other than the first optical disc is used, the light beam for the one of the at least two types of optical discs other than the first optical disc passed through all of said inner region, said intermediate region and said outer region is utilized.

18. The objective lens according to claim 15,

wherein the transmissivity for the light beam having the wavelength suitable for the first optical disc in said intermediate region is about half of transmissivity for the light beam having the wavelength suitable for the first optical disc in said inner region.

19. An objective lens used for an optical system of an optical pick-up for recording data to and/or reproducing data from at least two types of optical discs including a first optical disc and a second optical disc whose recording density is higher than that of the first optical disc, one of surfaces of said objective lens comprising:

an inner region including an optical axis of said objective lens and satisfying a numerical aperture for the first optical disc;

an outer region located outside said inner region for satisfying a numerical aperture for the second optical disc;  
and

an intermediate region that is located within said outer region at a periphery of the inner region,

wherein said intermediate region has a plurality of minute annular zones for giving optical path differences to an incident beam, an absolute value of each optical path difference generated between adjacent ones of the plurality of minute annular zones being  $N+0.5$  times ( $N$ : natural number) as large as the wavelength of the light beam suitable for the first optical disc.

20. The objective lens according to claim 19,

wherein when the first optical disc is tilted by a certain minute angle with respect to a plane perpendicular to the optical axis of said objective lens during reproducing operation of the first optical disc, a portion of returning light from a disc side is incident on said intermediate region, the portion of returning light incident on said intermediate region being diffused by said intermediate region by a large amount.

21. The objective lens according to claim 19, wherein  $N$  is smaller than or equal to 5.

22. The objective lens according to claim 19,

wherein the each optical path difference generated

between adjacent ones of the plurality of minute annular zones is an integral multiple of the wavelength of a light beam for one of the at least two types of optical discs other than the first optical disc, the integral multiple being exclusive of zero,

wherein when the one of the at least two types of optical discs other than the first optical disc is used, the light beam for the one of the at least two types of optical discs other than the first optical disc passed through all of said inner region, said intermediate region and said outer region is utilized.

23. The objective lens according to claim 19,

wherein the plurality of minute annular zones has repetition of a pair of zones that give optical path differences whose signs are different from each other.

24. The objective lens according to claim 23,

wherein a size of each of protruded surfaces of the plurality of minute annular zones is larger than a size of each of recessed surfaces of the plurality of minute annular zones.

25. The objective lens according to claim 19,

wherein a width  $W_z$  of each of the plurality of minute annular zones satisfies  $0.005 \text{ mm} \leq W_z \leq 0.020 \text{ mm}$  when the

plurality of minute annular zones are projected to a plane perpendicular to the optical axis of said objective lens.

26. The objective lens according to claim 19,  
wherein said objective lens satisfies a condition:

$$0.0035 < W/\{(1-M) \cdot f\} < 0.0350 \quad \cdots \cdots (2)$$

where W (mm) represents a width of said intermediate region when the intermediate region is projected onto a plane perpendicular to the optical axis said objective lens, f (mm) represents a focal length of said objective lens for the wavelength of the light beam for the first optical disc, and M represents a magnification of said objective lens when the first optical disc is used.

27. The objective lens according to claim 19, wherein said intermediate region adjoins said inner region.